Fact Sheet:

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Smart Structural Systems for Infrastructure Applications

The Problem

Deterioration of structures due to corrosion is a great contributor to the billions of dollars lost annually to infrastructure decay. Use of heavy equipment mandated by the weight of massive concrete and steel based structural elements adds significantly to the cost of new construction, and to the difficulty of construction in remote regions. Use of advanced structural composites containing graphite and fiberglass reinforced resins can eliminate corrosion and reduce weight. However, increased acceptance of advanced composites in construction necessitates improved quality control/assurance (QC/QA) and wireless in-service monitoring techniques to assure reliability.

The Technology

Smart Structural Systems Research & Development technologies will lead to self-diagnostic technologies in which the structure (or component) senses and reports aberrant performance and possibly corrects it by incorporating adaptive mechanisms. This R&D is focused on producing smart sensored structural elements, health monitored composite upgrade/repair systems, and real-time or on-demand wireless sensor packages. Future R&D includes self-repairing materials, ferrous SMA rebar and functionally gradient materials.

The U.S. Army Corps of Engineers Construction Engineering Research Laboratories (CERL), in joint research with the Society of the Plastic Industry s

Composite Institute (CI), is continuing the development of QC/QA testing of advanced composite materials through active and passive tagging. Tagging involves embedding micron-size sensors particles or macro patches into materials, such as advanced polymer composites. These embedded (or tagging) sensors interact with their host structures and generate certain types of measurable signatures which may be correlated with structural information, such as internal stress, strain, temperature, voids, chemical degradation, etc. The evaluation of these smart composites can be made during fabrication or in-service to provide information on structural health of the composite. The following tagging technologies have been applied to advanced composite materials:

1. Active tagging with ferromagnetic materials provides an inexpensive qualitative damage assessment capability.
2. Active tagging with magnetostrictive tags (materials which give off a magnetic field with applied load, and vice-versa) provide a real-time or on-demand wireless load indicator.
3. Piezoelectric patches applied to the surface of a composite reinforcement provide a remote qualitative composite/concrete or composite/metal debond indicator.

Through a Phase I Small Business Innovative Research (SBIR) effort with Strain Monitoring Systems, a wireless sensor system based on TRIP steel is being developed. TRIP steel exists as a non-magnetic material in its unstressed state. With the application of stress, the crystallographic nature of the material changes, causing the material to become increasingly magnetic. Using an arrangement of Hall effect (magnetic field) sensors, TRIP steel sensors, and remote data acquisition equipment, remote readings of peak strains and other structurally significant measurements can be determined in structures from a remote location.

Benefits/Savings

Smart structural systems based on polymer composites can be used to upgrade or civil structures to drastically reduce the cost of maintenance. The lighter weight of many advanced composite structural elements, often coupled with environmental advantages and lower energy consumption during fabrication, offer advantages in erection and shipping costs, especially in remote locations. The use of smart materials in conjunction with advanced composites provides greater information agility and will open the door to changes in the conservative use of materials for Army infrastructure applications.

Reduced cost of facilities operations and maintenance and extension of facility life by 10-30 years make smart structural systems appealing for some of the 190,000+ Army buildings for which no adequate health monitoring exists. This technology will result in a 20% reduction in life cycle costs along with reduced first costs to facilitate in the optimization of the Army s $3.8B in Backlog of Maintenance and Repair (BMAR).

Status

This research and development (R&D) is a joint government/industry program. The CI and several composites industry organizations join CERL in work on the project. These companies will fund significant portions of the R&D, including much of the actual materials fabrication and testing at their facilities. Promising tag materials have been selected, tag interactive models have been developed, and fabrication of lab samples and full scale C-channels of tagged composites has been initiated. The health monitoring of composites are to be evaluated on unreinforced masonry structures using piezopatch and TRIP steel sensors. In addition, the health monitoring of concrete is being evaluated using Electrical Time Domain Reflectometry (ETDR).

Point of Contact

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